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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))

Attorney Docket No.	9351-21/HSF
First Inventor or Application Identifier	Cargnelli et al.
Title	Method and Apparatus for Humidification and Temperature..
Express Mail Label No.	

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231

1. [ ] * Fee Transmittal Form *(e.g., PTO/SB/17)* *(Submit an original and a duplicate for fee processing)*
2. [✔] Specification [Total Pages 15] *(preferred arrangement set forth below)*
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (if filed)
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. [✔] Drawing(s) *(35 U.S.C. 113)* [Total Sheets 5]
4. Oath or Declaration [Total Pages 4]
   a. [ ] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 C.F.R. § 1.63(d)) *(for continuation/divisional with Box 16 completed)*
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).

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5. [ ] Microfiche Computer Program *(Appendix)*
6. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
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ACCOMPANYING APPLICATION PARTS

7. [ ] Assignment Papers (cover sheet & document(s))
8. [ ] 37 C.F.R.§3.73(b) Statement *(when there is an assignee)* [ ] Power of Attorney
9. [ ] English Translation Document *(if applicable)*
10. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
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Signature		*Date*	July 28, 2000

B&P File No. 9351-21

BERESKIN & PARR **UNITED STATES**

TITLE: METHOD AND APPARATUS FOR HUMIDIFICATION AND TEMPERATURE CONTROL OF INCOMING FUEL CELL PROCESS GAS

Inventor(s): Joe Cargnelli
Ravi Gopal

Title: METHOD AND APPARATUS FOR HUMIDIFICATION AND TEMPERATURE CONTROL OF INCOMING FUEL CELL PROCESS GAS

FIELD OF THE INVENTION

The present invention relates generally to a method and apparatus for humidifying and controlling the temperature of incoming fuel cell process gas. More particularly, the present invention relates to a humidification system capable of providing rapid, accurate and precise control of both the relative humidity and the temperature of the incoming fuel cell process gas.

BACKGROUND OF THE INVENTION

Fuel cell systems are seen as a promising alternative to traditional power generation technologies due to their low emissions, high efficiency and ease of operation. Fuel cells operate to convert chemical energy into electrical energy. Proton exchange membrane fuel cells comprise an anode, a cathode, and a selective electrolytic membrane disposed between the two electrodes. In a catalyzed reaction, a fuel such as hydrogen, is oxidized at the anode to form cations (protons) and electrons. The ion exchange membrane facilitates the migration of protons from the anode to the cathode. The electrons cannot pass through the membrane and are forced to flow through an external circuit thus providing an electrical current. At the cathode, oxygen reacts at the catalyst layer, with electrons returned from the electrical circuit, to form anions. The anions formed at the cathode react with the protons that have crossed the membrane to form liquid water as the reaction product.

Proton exchange membranes require a wet surface to facilitate the conduction of protons from the anode to the cathode, and otherwise to maintain the membranes electrically conductive. It has been suggested that each proton that moves through the membrane drags at least two or three water molecules with it (U.S. Patent 5,996,976). U.S. Patent 5,786,104 describes in more qualitative terms a mechanism termed "water pumping", which results in the transport of cations (protons) with water molecules through the membrane. As the current density increases, the number of

water molecules moved through the membrane also increases. Eventually the flux of water being pulled through the membrane by the proton flux exceeds the rate at which water is replenished by diffusion. At this point the membrane begins to dry out, at least on the anode side, and its internal resistance increases. It will be appreciated that this mechanism drives water to the cathode side, and additionally the water created by reaction is formed at the cathode side. Nonetheless, it is possible for the flow of gas across the cathode side to be sufficient to remove this water, resulting in drying out on the cathode side as well. Accordingly, the surface of the membrane must remain moist at all times. Therefore, to ensure adequate efficiency, the process gases must have, on entering the fuel cell, a predetermined or set relative humidity and a predetermined or set temperature which are based on the system requirements.

A further consideration is that there is an increasing interest in using fuel cells in transport and like applications, e.g. as the basic power source for cars, buses and even larger vehicles. As compared to some stationary applications, this presents some unique requirements. More particularly, it is necessary that the power delivered by a fuel cell be capable of rapid change between different power levels, and these power levels can be quite different. Thus, in urban driving, it is common for fuel cells to be required to frequently switch between minimum, or even zero power, to a maximum power level and back again. Maintaining appropriate humidity levels under such severe operating conditions is not easy. Additionally, a fuel cell must be capable of providing this functionality under a wide range of ambient air conditions.

Accordingly, in this art one can find numerous proposals for maintaining humidity in fuel cell systems. One conventional way to humidify a gas stream is to pass a gas as a stream of fine bubbles through water. As long as the process gas has sufficient contact time with the water, controlling the temperature of the water controls the amount of water in the gas stream. However, these bubble column type humidifiers are generally not suitable for fuel cells. The humidifiers tend to be large and costly. Moreover, the humidifiers are unable to react fast enough to meet the load following requirements of the fuel cell system. As a result, at high gas flow

rates the system becomes unstable ,unreliable and unresponsive. In addition, this humidification system never reaches 100% relative humidity in practice and this limits the flexibility or adaptability of the system.

In some prior art fuel cells, incoming process gases are humidified by flowing each gas on one side of a water vapor exchange membrane and by flowing deionized water on the opposite side of the membrane. In this way, water is osmotically transferred across the membrane to the fuel and oxidant gases. However, these systems have process parameter restraints that cause problems and inefficiencies when used in conjunction with fuel cells. Since the membrane is at the same temperature as the fuel stack, there is no independent control of the relative humidity or temperature of the process gases and thus the system is limited in its ability to adjust to different situations.

Other humidification methods include exposing the incoming process gas to a source of steam or metering in a quantity of fine water droplets into the gas supply line (U.S. Patent 5,432,020). However, in the past, these systems tended to be large, complex, slow acting, and possessed inadequate dynamic controllability.

There remains a need for a humidifier that can offer rapid dynamic control, as well as precise and accurate temperatures and relative humidities for incoming fuel cell process gases. More particularly, such a humidifier should enable relative humidity and temperature to be controlled independently over a wide variety of flow rates, for both the oxidant and fuel systems.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a method for humidifying a process gas stream, the method comprising the steps of:

(a) super-saturating and heating the process gas stream with steam until it reaches a first pre-set temperature;

(b) cooling the process gas stream until it reaches a second pre-set temperature;

(c) removing excess condensed water from the process gas stream; and

(d) heating the process gas stream until it reaches a third pre-set temperature.

In one embodiment, the method further comprises the step of maintaining the third pre-set temperature of the process gas stream from step (d) until it reaches an inlet of a fuel cell.

In accordance with another embodiment of the present invention, there is provided an apparatus for humidifying a process gas stream for an operating fuel cell, the apparatus comprising:

(a) a means for super-saturating and heating the process gas stream with steam until it reaches a first pre-set temperature;

(b) a means for cooling the process gas stream until it reaches a second pre set temperature;

(c) a means for removing excess condensed water from the process gas stream; and

(d) a means for heating the process gas stream until it reaches a third pre-set temperature.

In one embodiment, the apparatus further comprises a means for maintaining the third pre-set temperature of the process gas stream from step (d) until it reaches an inlet of a fuel cell.

The present invention has many advantages over the prior art. The combination of the dewpoint cooling section and reheating section allows rapid changes in operating conditions, with response times that are less than 30 seconds. Furthermore, the system can be dynamically controlled to provide precise and accurate inlet fuel process gas stream temperatures and relative humidities, which are both essential for the efficient operation of a proton exchange membrane fuel cell over a wide range of current densities.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

For a better understanding of the present invention, and to show more clearly how it may be carried into effect, reference will now be made,

by way of example, to the accompanying drawings, which show a preferred embodiment of the present invention and in which:

Figure 1 illustrates a schematic flow diagram of one embodiment of a humidification system for a fuel cell;

Figure 2 shows a perspective view of a second embodiment of the humidification system for a fuel cell;

Figure 3 shows a detail of Figure 2 in a corresponding perspective view on a larger scale;

Figure 4 shows a perspective view of part D of Figure 3 in a corresponding perspective view on an enlarged scale;

Figure 5 shows details of elements of a steam line;

Figure 6 shows a part of figure 5 on an enlarged scale; and

Figure 7 shows a schematic view of the humidification system of the second embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to Figure 1, this shows a schematic flow diagram of a process gas stream for one process gas. It is to be understood that the invention is applicable to both gases, i.e. to both of the fuel and the oxidant, and for this purpose the flow diagram of Figure 1 would be duplicated for the two process gas lines. The embodiments of Figure 2-6 shows the invention as applied to both process gas lines

Referring to Figure 1, and in that process gas stream 12 and a steam line 14 are both connected to a saturator 16, for increasing the humidity of the gas stream. Steam is supplied from a steam supply indicated schematically at 18. The saturator 16 includes an injector for injecting steam into the process gas stream, so as to both heat and humidify the process gas stream.

A line 20 exits from the saturator 16 and contains super-saturated process gas. The line 20 enters a first heat exchanger 22. The first heat exchanger 22 can be a plate heat exchanger or other suitable heat exchanger, and has an inlet 26 and an outlet 28 for a water stream. It is to be understood that the stream could be comprised of at least one fluid, including but not limited to water, oil, and/or ethylene glycol. While a

variety of heat exchange fluids could be used for the specific embodiments described here, all the heat exchange fluids are water in the described embodiments. The inlet and outlet 26, 28 are part of a first temperature control circuit, also referred to as a dewpoint cooling section, including a pump 30, an inlet 32 for make-up water and a third heat exchanger 34. Additionally a first heater 36 is provided. Thus, in the first temperature control circuit, the make up water enables the level of fluid to be maintained, and this stream can be either cooled with the third heat exchanger 34 or heated with the first heater 36 to a desired temperature.

The first heat exchanger 22 has an outlet for cooled gas connected by a line 24 to a separator 38. The separator 38 is for separating water condensed out of the gas in the first heat exchanger 22, and has a discharge or outlet 40 for condensed water. An outlet of the separator 38 is connected by a further line 42 to a second heat exchanger 44.

The second heat exchanger 44 is intended to reheat the gas, and has an outlet connected to line 46 for the reheated gas. Like the first heat exchanger 22, the second heat exchanger 44 has an inlet 48 and an outlet 50 for a water heating stream. The inlet and outlet 48 ,50 are part of a second temperature control circuit, also referred to as a reheating section, including a pump 52, a make-up inlet 54 , a fourth heat exchanger 55, and a second heater 56.. Thus, like the arrangement of the first heat exchanger 22, the pump 52 circulates the make up water, and this stream can be either cooled with the fourth heat exchanger 55 or heated with the second heater 56 to a desired temperature.

The reheated gas with the known moisture content is then passed through line 46 to the fuel cell stack indicated schematically at 60.

The arrangement of Figure 1 is intended to provide controlled humidification of the gas stream supplied to the fuel cell stack 60, and to enable both the temperature and humidity to be precisely controlled. This is explained further, by the detailed description of the mode of operation of the apparatus of Figure 1. Thus, dry incoming process is supplied to the saturator 16, and gas is super-saturated with steam in the saturator 16, to a humidity level greater then that ultimately desired for the gas. Both the

flow of the gas through line 12 and steam through line 14 are controlled and metered . The effect of injecting steam into the gas is also to heat the gas to a first pre-set temperature. Typically, on leaving the saturator 16, the gas is supersaturated at the first pre-set temperature of around 90°C, although the gas may be supersaturated at any temperature in the range of 10°C to 120°C.

In the first heat exchanger 22, the gas is cooled down to a second pre-set temperature of, for example, 80°C. Again, for example, this temperature could be in the range 10°C to 120°C. The effect of this is to remove excess moisture from the gas stream, and to give a humidity level equal to 100% relative humidity at the temperature to which the gas is cooled in the first heat exchanger 22.

The reason for first super-saturating and then cooling the gas to remove excess moisture is to ensure that the absolute humidity level is accurately achieved. Achieving a reliable humidity level in the saturator 16 is not practical. Thus, the approach has been taken of adding excess moisture and then removing excess moisture by condensation, since the absolute humidity level is known, when the gas is saturated and the dewpoint temperature of the gas is known.

The excess moisture in the gas will form droplets, and the gas with the condensed droplets is passed to the separator 38, where the condensed droplets are collected or separated from the gas flow and drained out through the outlet or discharge line 40.

The saturated gas is then passed through line 42 to the second heat exchanger 44. Here, the gas is reheated to a third pre-set temperature of, for example, 85°C. More generally, the gas can be reheated to a temperature of 10°C to 120°C. Heating the gas will reduce the relative humidity level but the absolute humidity level will remain constant .

Thus, reheated process gas from the second heat exchanger 44, passes through line 46, and it will then have a known, third pre-set temperature and a known humidity level. As indicated schematically at 58, a heater is provided to maintain the line 46 at a constant temperature, to ensure that the gas does not cool or otherwise change in temperature during passage to the fuel cell stack 60. Practically, it has been found that heat traces, comprising electrical heating wires, wound around the line 46

provides a necessary heating function. This ensures a gas delivered to fuel cell stack 60 is at the desired temperature and with the desired humidity.

As mentioned above, changing demands on the fuel cell stack are accomplished by changing the flow rate for the gas passing through the line 12. If it is desired to change the temperature and/or the humidity of the gas flow then this is achieved by control of the operating conditions of the first and second heat exchangers 22, 24.

Thus, the temperature of the cooling fluid in the first temperature control loop or circuit of the first heat exchanger 22, passing through the inlet and outlet 26, 28, is controlled, so as to control the temperature of gas exiting from the heat exchanger 22, and hence the absolute humidity level of this gas.

Commonly, it is expected that gas will be cooled in the first heat exchanger 22, and the second heat exchanger 44 will ensure that the cooling water passing through the cooling loop will be at a desired temperature. The third heat exchanger 34 enables the temperature in the cooling loop to be lowered quickly if desired.

Where the operational requirement is to increase the temperature of the gas exiting from the first heat exchanger 22, then the water in the cooling loop needs to be heated. For this purpose, the first heater 36 is provided to enable the water to be rapidly heated. It has been found, in practice, that response times of less than a minute can be provided for a 12kW fuel cell.

Correspondingly, in the second heat exchanger 44, the second heater 56 is adjusted to heat water in a cooling loop passing through the inlet and outlet 48 and 50 to the desired temperature. The fourth heat exchanger 55 enables the temperature in the cooling loop to be lowered quickly if desired.

Reference will now be made to Figures 2-7, which show an implementation of the present invention.

Referring to Figure 7, there is shown a schematic view of a humidification circuit according to a second embodiment. Here, a steam inlet 70 is connected to a steam supply and is provided with a pressure sensor 72, connected to a pressure switch (not shown) for tripping the fuel

cell system if the steam supply pressure is too low.. The line 70 then passes through a main shut off valve 74 and a trap 76 is provided for draining off any condensation which may have formed.

The steam line 70 then passes through a T-connection to two separate lines 90, 92 for supplying steam to the separate gas lines for the fuel and oxidant gases. Many elements of these two lines 90, 92 are common, and for simplicity, a description is given just of these elements in the line 90. The corresponding elements in the line 92 are given the same reference numeral but with a suffix "a", it being understood that they have essentially the same function.

Thus, the line 90 includes a steam regulator or shut off valve 94 connected to a further regulating valve 96 Valve 96 is a metering valve which controls the flow of steam into the gas lines.

A fuel gas is supplied through a line 112. Steam is injected into the fuel gas at an injection port 114. Steam is supplied to injection port 114 through a non-return valve 116.

The fuel gas containing steam, which is then in a supersaturated condition passes through a first heat exchanger 118, which is cooled, so as to promote condensation of excess moisture.

The cooled fuel gas then passes to a separator 120 with a trap and drain arrangement 122, for separating out also droplets. The fuel gas with 100% relative humidity then flows through a line 124, that is insulated to maintain the temperature and humidity level of the fuel gas to a second heat exchanger 126. A temperature sensor 128 is provided downstream from a separator 120, for detecting the temperature of the fuel gas stream. Knowing that the fuel gas stream will be at a 100% relative humidity, the absolute humidity of the gas stream can be determined.

From the second heat exchanger 126, the fuel gas flows to the fuel cell stack indicated at 130. Again, standard sensors can be provided as indicated at 132, immediately before the inlet to the fuel cell.

Each of the first and second heat exchangers 118, 126 has its respective temperature control circuit, and these are now described separately.

Referring first to the first heat exchanger 118, a temperature control circuit indicated at generally 132 includes a first secondary heat exchanger 134, a pump 136 and a heater 138.

Auxiliary elements of the circuit include a connection 140 for make up water and a pressure relief valve 142. Chilled cooling water is supplied to the secondary heat exchanger 134 through supply and return lines 144 and 146 with a control valve being provided at 148. A temperature sensor 150 is provided in the cooling circuit, to enable the temperature in the first heat exchanger 118 to be set as desired. Other standard control elements would be provided as required. For example, a temperature controller 152 is connected to the temperature sensor 150 and to the heater 138, and also to the control valve 148. Thus, the temperature controller 152 can open the valve 148 to increase the flow of cooling water to cool down the temperature in the circuit, or alternatively actuate the heater 138 to increase the temperature in the circuit, as required.

The temperature control circuit for the second heat exchanger 126 generally corresponds. Thus, the circuit is indicated at 162, and includes a second secondary heat exchanger 164, a pump 166 and a heater 168. A make up inlet 170 is provided, together with a pressure release valve 172.

The chilled water supply and return lines 144, 146 are connected through the second secondary heat exchanger 164, through a control valve 178.

A temperature sensor 180 is connected to the second temperature control circuit 162, and a temperature controller 182 is connected to a temperature sensor 180, control valve 178 and the heater 168, for control as for the first temperature control circuit 132.

The present invention has many advantages over the prior art. The combination of the dewpoint cooling section and the reheating section allows rapid changes in operating conditions, with typical response times which are less than one minute. Furthermore, the system can be dynamically controlled to provide precise and accurate inlet fuel process gas stream temperatures and relative humidities, which are both essential for the efficient operation of a proton exchange membrane fuel cell over a wide range of current densities.

While the above description constitutes the preferred embodiments, it will be appreciated that the present invention is susceptible to modification and change without departing from the fair meaning of the proper scope of the accompanying claims. For example, the present invention might have applicability in other types of fuel cells, which include but are not limited to, solid oxide, alkaline, molton-carbonate, and phosphoric acid. In particular, the present invention may be applied to fuel cells which operate at much higher temperatures. As will be appreciated by those skilled in the art, the requirement for humidification is very dependent on the electrolyte used and also the temperature and pressure of operation of the fuel cell. Accordingly, it will be understood that the present invention may not be applicable to all other types of fuel cells.

CLAIMS:

1. A method of humidifying a process gas stream, the method comprising;

(a) humidifying the process gas stream at a first temperature so as to provide the process gas stream with excess humidity;

(b) cooling the process gas stream at a second temperature, lower than the first temperature, to cause condensation of excess moisture;

(c) removing excess condensed moisture from the process gas stream; and

(d) delivering the process gas stream at a known temperature, whereby the absolute humidity level in the process gas stream is determined from the maximum relative humidity at the second temperature.

2. A method as claimed in claim 1, wherein step (d) includes heating the process gas stream to a third temperature greater than the second temperature.

3. A method as claimed in claim 2, which includes humidifying the process gas stream in step (a) by injecting steam into the process gas stream.

4. A method as claimed in claim 3, which includes injecting steam into the gas stream in an amount sufficient to supersaturate the process gas stream.

5. A method as claimed in claim 2, which further comprises the step of supplying the humidified process gas stream at the third temperature to a fuel cell, and maintaining the third temperature of the process gas stream from step (d) at the third temperature, until the process gas stream reaches the inlet of a fuel cell.

6. A method as claimed in claim 5, which includes maintaining the third temperature of the process gas stream, by delivering the process gas stream through a supply line, and providing a heating element extending along the supply line.

7. A method as claimed in claim 2, wherein the first temperature is in the range 10 °C to 120 °C.

8. A method as claimed in claim 7, wherein the second temperature is in the range 5 °C to 115 °C.

9. A method as claimed in claim 8, wherein the third temperature is in the range 10 °C to 120 °C, and wherein the relative humidity of the process gas stream at the third temperature is in the range of 0 to 100%.

10. An apparatus for humidifying a process gas stream, for a fuel cell, the apparatus comprising:

a humidification unit having an inlet for the process gas stream, for adding humidity to the process gas stream at a first temperature, to a humidity well in excess of a required humidity level;

a first heat exchanger connected to the humidification unit, for cooling the process gas stream to a second, lower temperature, whereby excess moisture in the process gas stream condenses, and for removing the condensed moisture, whereby the process gas stream leaving the heat exchanger has a known temperature and a known humidity level.

11. An apparatus as claimed in claim 10, which includes a first heater connected to the first heat exchanger, for heating the process gas stream to a third temperature, greater than the second temperature, whereby the process gas stream has a known absolute humidity level.

12 An apparatus as claimed in claim 11, wherein the humidification unit includes a steam injector for injecting steam into the process gas stream.

13. An apparatus as claimed in claim 11, which includes an outlet line connected to the first heater and an elongate heating means provided for the outlet line, for maintaining the outlet line at the third temperature.

14. An apparatus as claimed in claim 13, where the elongate heating means comprises elongate electrical heating elements.

15. An apparatus as claimed in claim 11, which includes a separator, for removing the condensed moisture, provided between the first heat exchanger and the first heater.

16. An apparatus as claimed in claim 11, wherein the first heat exchanger includes a first temperature control circuit, for controlling the temperature of the heat exchanger, the first temperature control circuit comprising a conduit for a fluid, a pump for pumping the fluid, and means for cooling the fluid.

17. An apparatus as claimed in claim 16, wherein the first cooling circuit additionally includes a further heater for heating the fluid.

18. An apparatus as claimed in claim 11 or 16, wherein the first heater comprises a second heat exchanger, and wherein the second heat exchanger is provided with a second temperature control circuit for controlling the temperature of the second heat exchanger, the second temperature control circuit comprising a conduit for fluid, a pump for circulating the fluid and a third heater for heating the fluid.

ABSTRACT

A method for humidifying and controlling the temperature of a process gas stream comprising the steps of super-saturating and heating the process gas stream with steam until it reaches a first pre-set temperature; cooling the process gas stream until it reaches a second pre-set temperature; removing excess condensed water from the process gas stream; and heating the process gas stream until it reaches a third pre-set temperature. An apparatus for implementing this method is also disclosed.

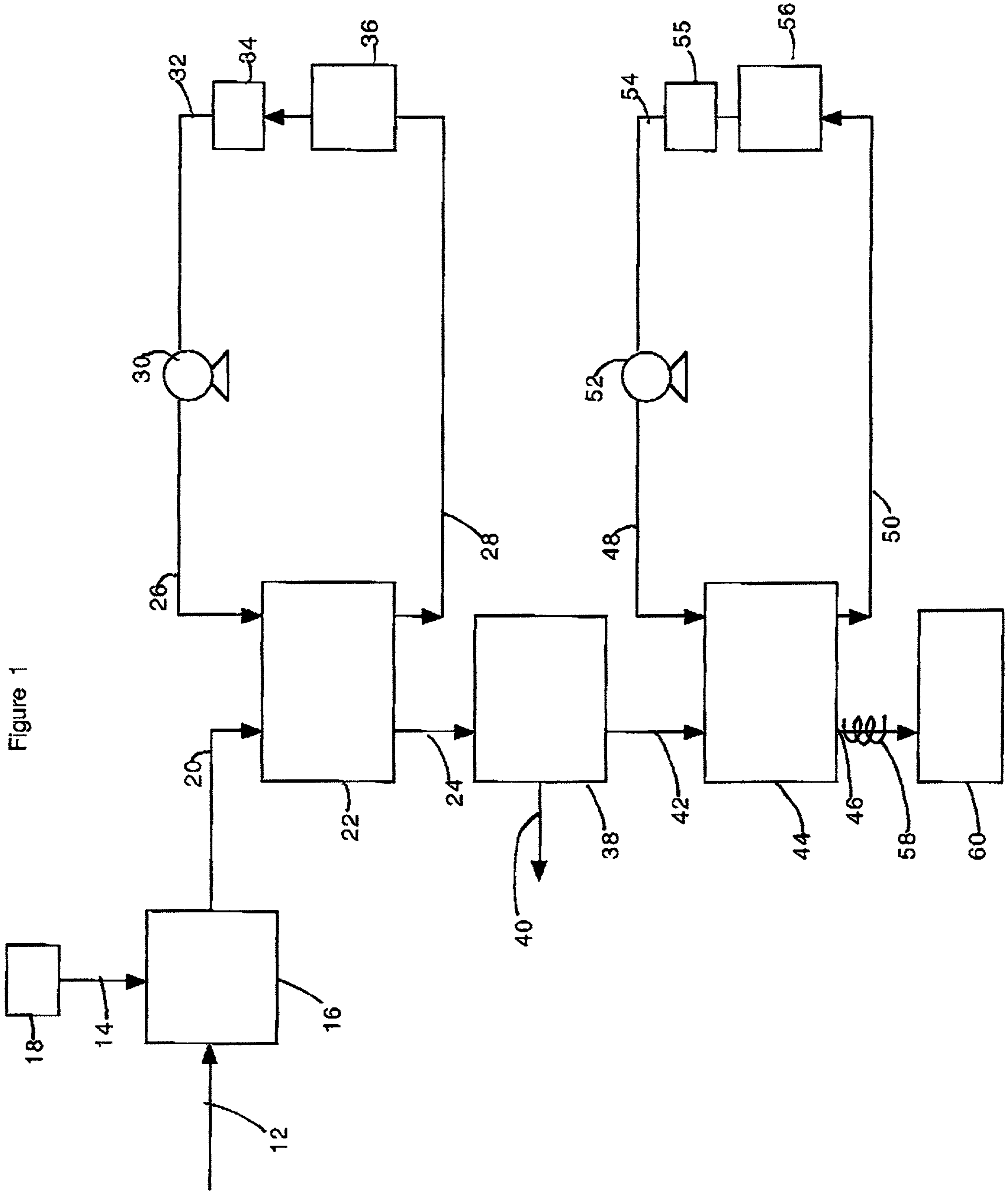
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Figure 1

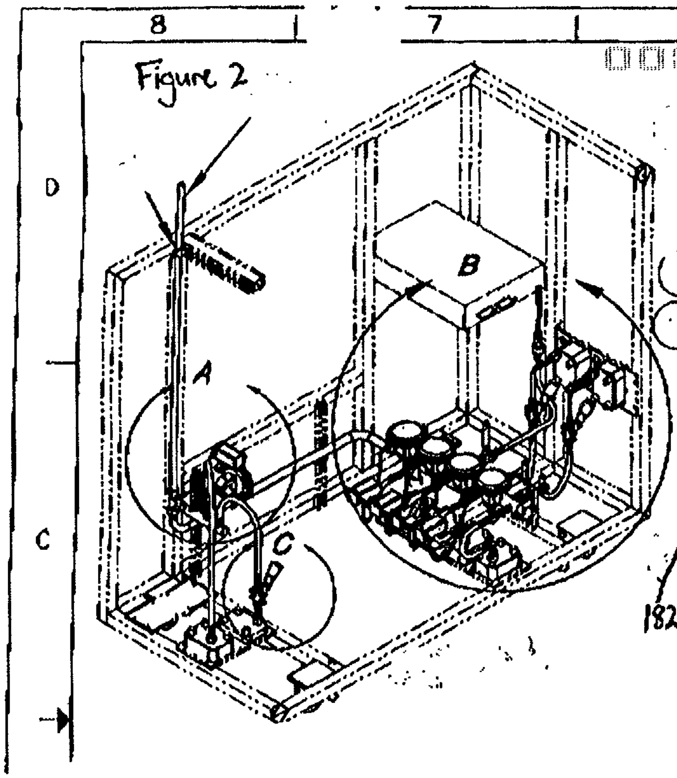

Figure 2

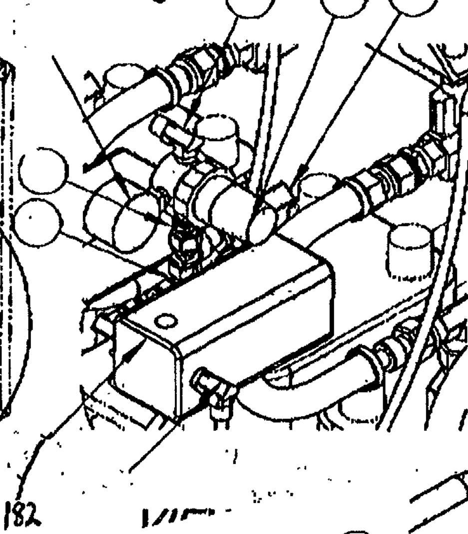

Figure 1

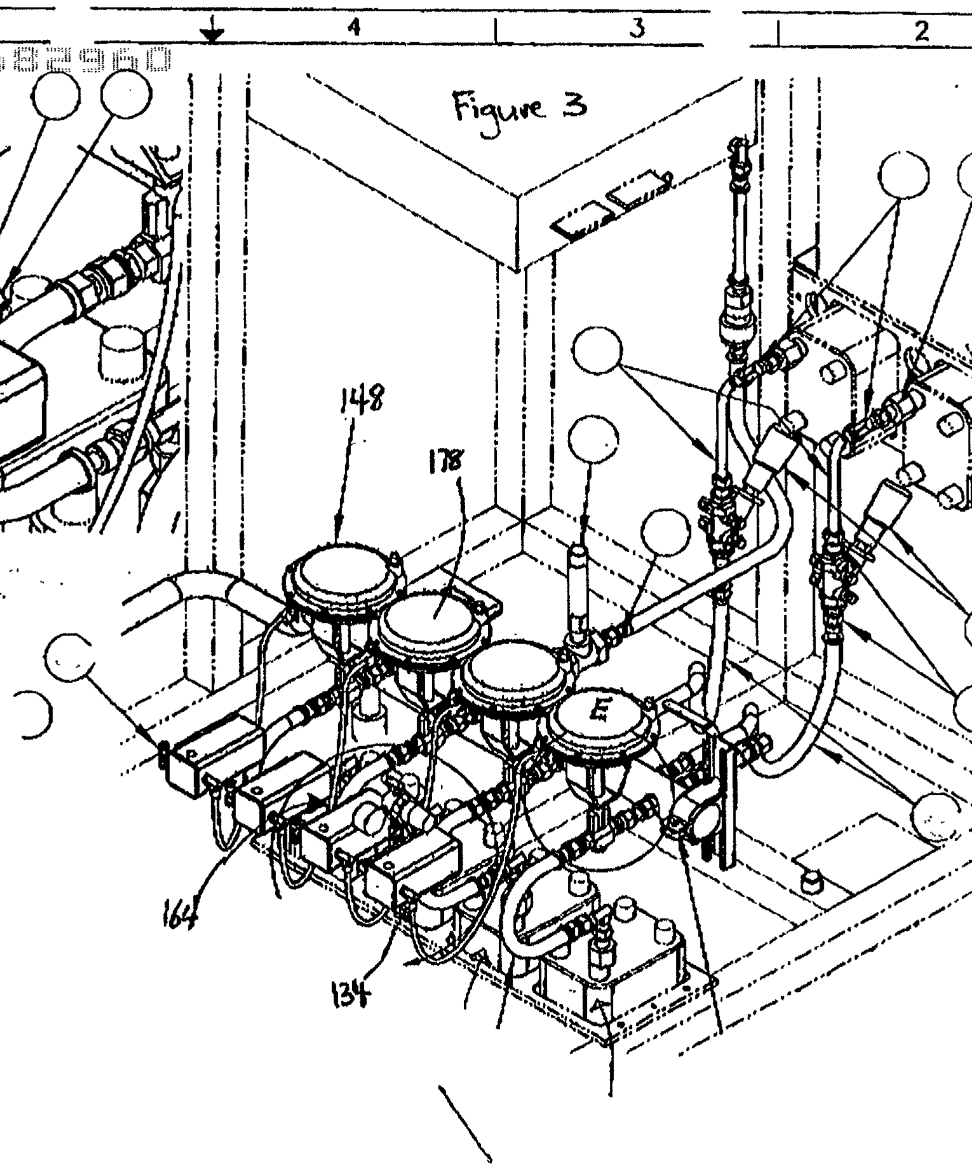

Figure 3

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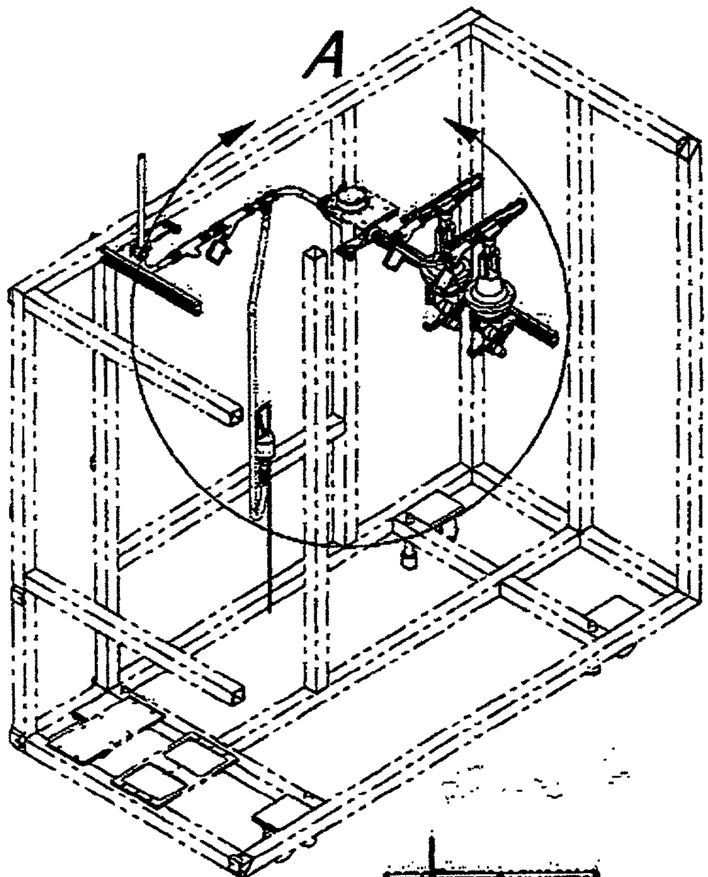
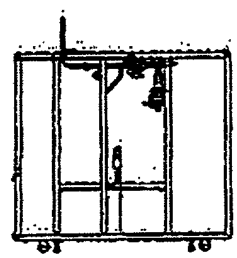
REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED

Figure 5





ELEVATION

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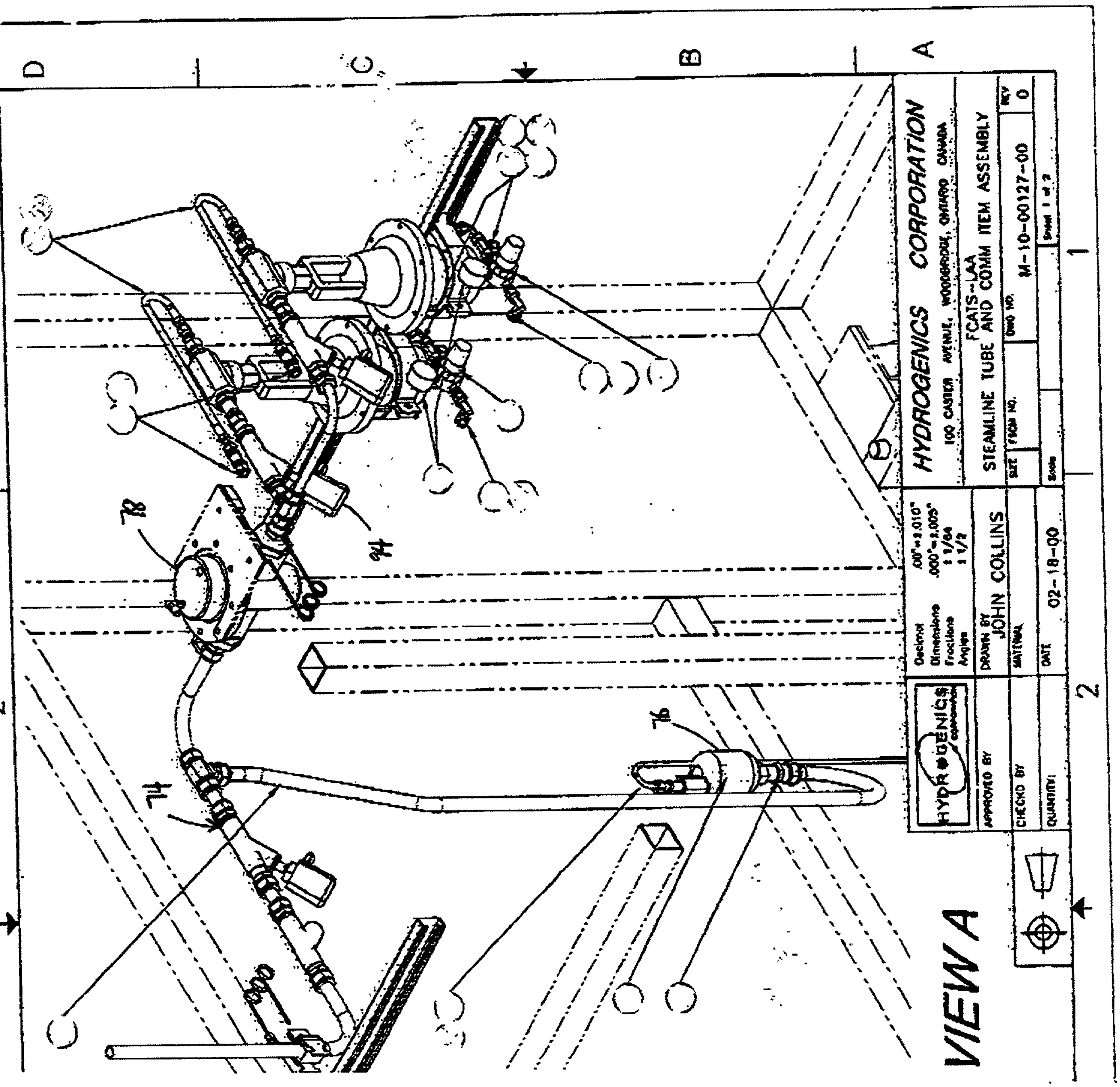
Figure 6



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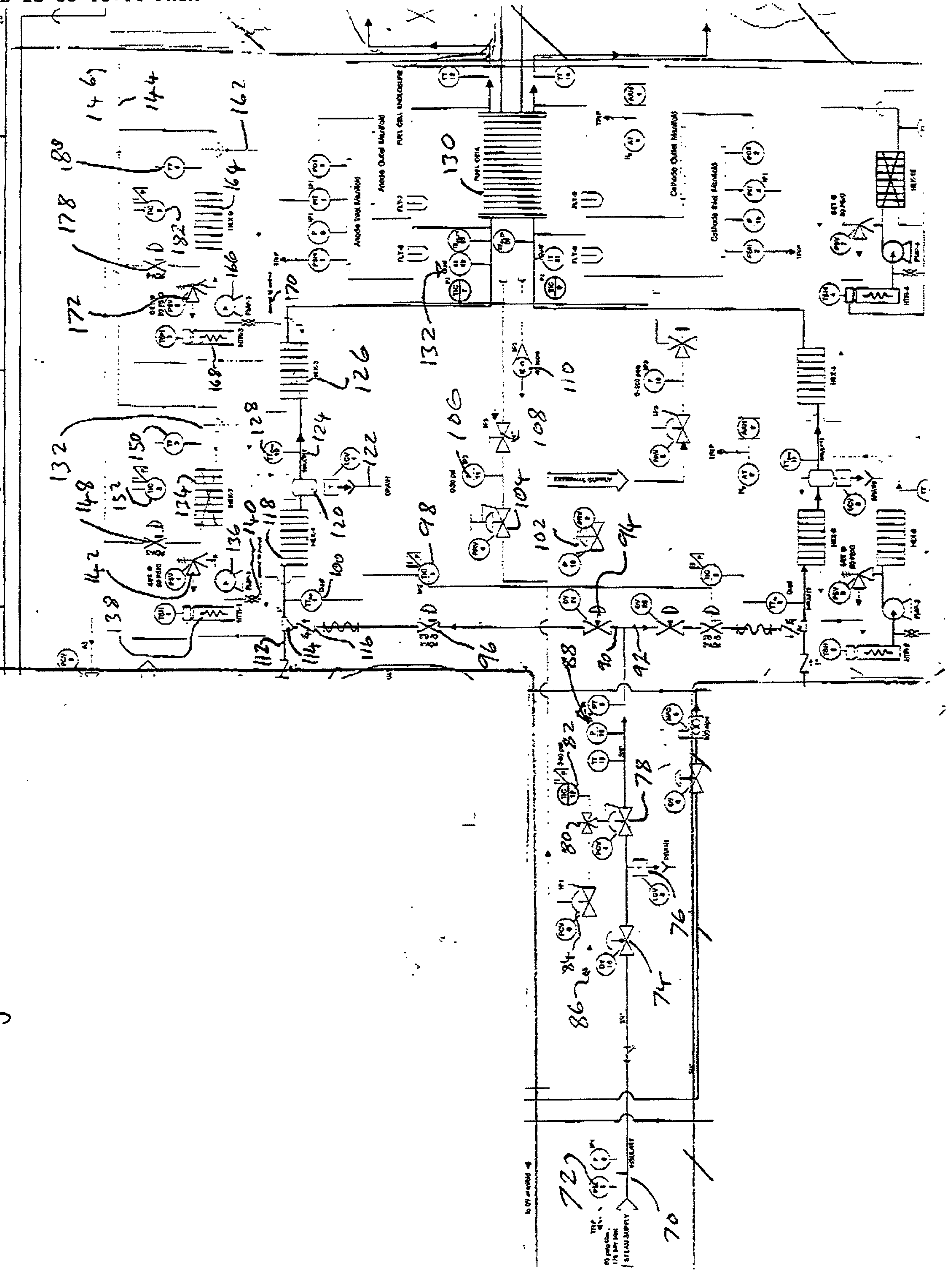
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Figure 7

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DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

☑ Declaration Submitted with Initial Filing OR ☐ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	9351-21/HSF
First Named Inventor	Cargnelli et al.
COMPLETE IF KNOWN	
Application Number	n/a
Filing Date	Filed concurrently herewith
Group Art Unit	n/a
Examiner Name	n/a

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD AND APPARATUS FOR HUMIDIFICATION AND TEMPERATURE CONTROL OF INCOMING FUEL CELL PROCESS GAS

(Title of the Invention)

the specification of which

☑ is attached hereto

OR

☐ was filed on (MM/DD/YYYY) ________ as United States Application Number or PCT International Application Number ________ and was amended on (MM/DD/YYYY) ________ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)

☐ Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

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DECLARATION — Utility or Design Patent Application

I hereby claim the benefit under 35 U.S.C. 120 of any United States application(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number *(if applicable)*

☐ Additional U.S. or PCT international application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

As a named inventor, I hereby appoint the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: ☑ Customer Number 1059 → *Place Customer Number Bar Code Label here*
OR
☐ Registered practitioner(s) name/registration number listed below

Name	Registration Number	Name	Registration Number
Daniel R. Bereskin	22,257	H. Samuel Frost	31,696
Richard J. Parr	22,836	Philip Mendes da Costa	33,106
H. Roger Hart	26,426	Robert B. Storey	33,108
David W.R. Langton	27,747	John R. Rudolph	38,003
C. Lloyd Sarginson	29,245	Robin L.A. Coster	38,016
Timothy J. Sinnott	31,083	Michael E. Charles	38,036

☑ Additional registered practitioner(s) named on supplemental Registered Practitioner Information sheet PTO/SB/02C attached hereto.

Direct all correspondence to: ☑ Customer Number or Bar Code Label 1059 OR ☐ Correspondence address below

Name	Bereskin & Parr				
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Address	40 King Street West				
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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of Sole or First Inventor: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname
Joe	Cargnelli

Inventor's Signature						Date	
Residence: City	Toronto	State	Ontario	Country	Canada	Citizenship	Canadian
Post Office Address	59 Lapp Street						
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City	Toronto	State	Ontario	ZIP	M6N 5W3	Country	Canada

☑ Additional inventors are being named on the X supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto

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ADDITIONAL INVENTOR(S)
Supplemental Sheet
Page 1 of 1

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor						
Given Name (first and middle [if any])				Family Name or Surname			
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Inventor's Signature						Date	
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Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor						
Given Name (first and middle [if any])				Family Name or Surname			
Inventor's Signature						Date	
Residence: City		State		Country		Citizenship	
Post Office Address							
Post Office Address							
City		State		ZIP		Country	

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor						
Given Name (first and middle [if any])				Family Name or Surname			
Inventor's Signature						Date	
Residence: City		State		Country		Citizenship	
Post Office Address							
Post Office Address							
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DECLARATION

REGISTERED PRACTITIONER INFORMATION (Supplemental Sheet)

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Andrew I. McIntosh	40,453	Stephen M. Beney	41,563
Shawn D. Jacka	43,379		